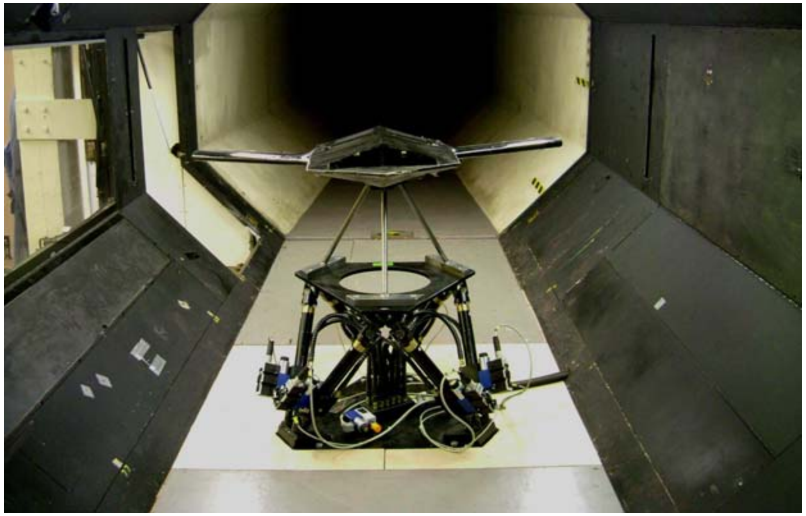
Flapless Flight Demonstrator Experience at Manchester



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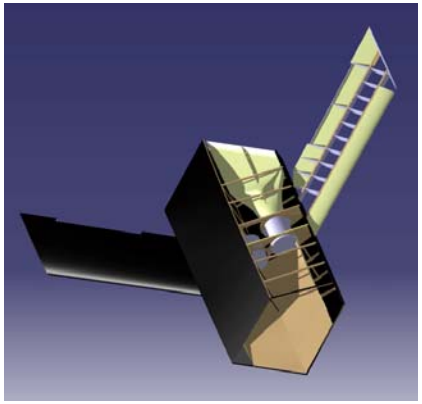
Presentation aims

- To describe a series of model-scale flight vehicles developed at the University of Manchester for the purpose of incrementally demonstrating fully controlled flight without any moving control surfaces
- To highlight the role of small-scale demonstrator work in pushing forward large research projects



Presentation Outline

- Introduction to the FLAVIIR research programme and the role of the work at Manchester
- Review of flapless manoeuvre effector technology – circulation control and fluid thrust vectoring
- Overview of the Manchester flight demonstrator programme
- Future outlook – the next steps
- Conclusions

Background to the FLAVIIR project

- The FLAVIIR project is a 5 year £6m ($10m) UK research program, funded jointly by BAE SYSTEMS and EPSRC, undertaken by 10 university partners developing aeronautical technologies for future unmanned air vehicles (UAVs). The focus for the research is the "Grand Challenge" laid down by BAE Systems:
- *"To develop technologies for a maintenance-free, low cost UAV without conventional control surfaces and without performance penalty over conventional craft"*

Demonstrator work at Manchester as part of FLAVIIR

Need to rapidly flight test novel controls technology

‘Seed corn’ funding (£37k) January 2005

Lab/wind tunnel work

Realisation of the magnitude of the task

Flight test

Finish

Aims of the ‘seed corn’ model scale flight demonstrator project

- To rapidly demonstrate flapless manoeuvre effector technology developed at Manchester through flight test of hardware at model scale

- To highlight potential integration issues on transfer of the technology to the full scale flight demonstrator

- To quantify systems impact of flapless control at model scale

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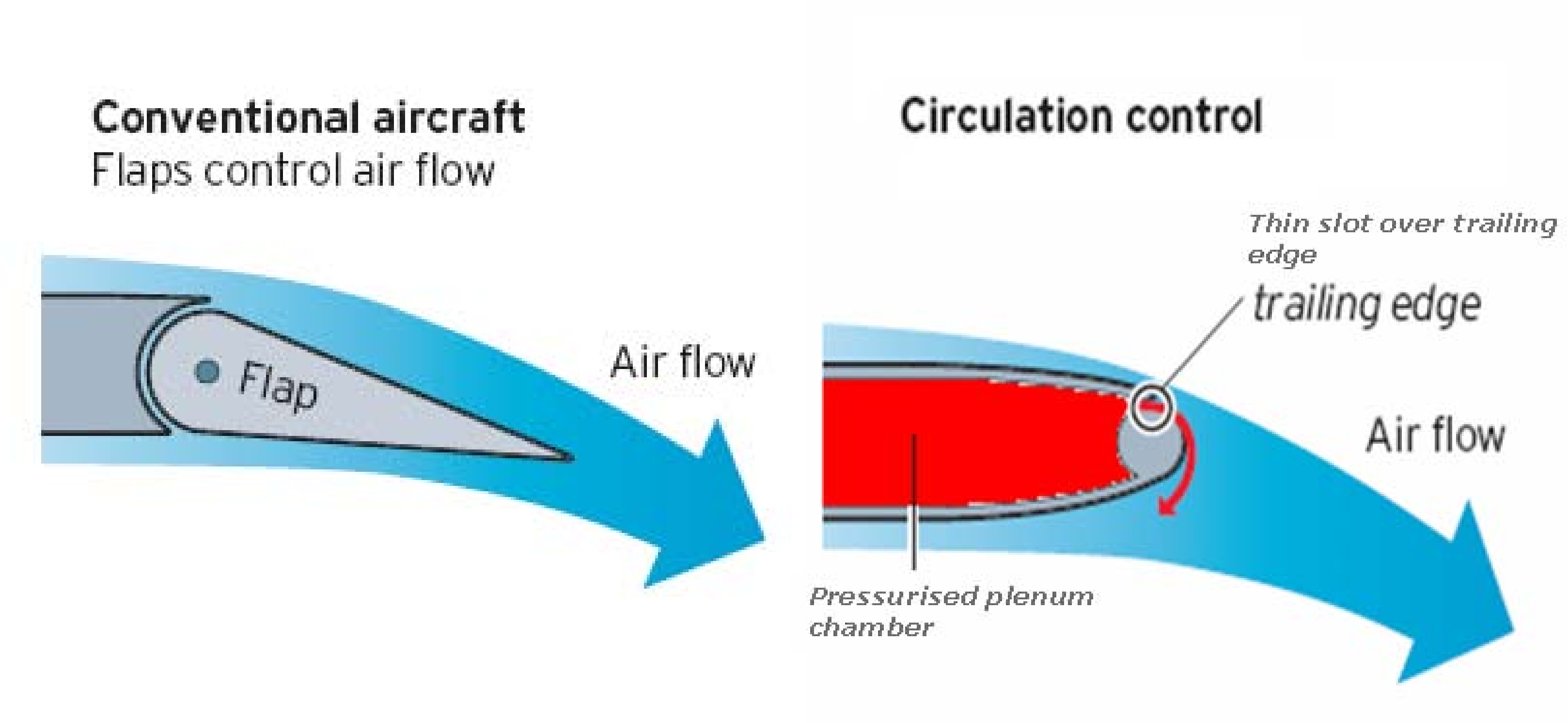
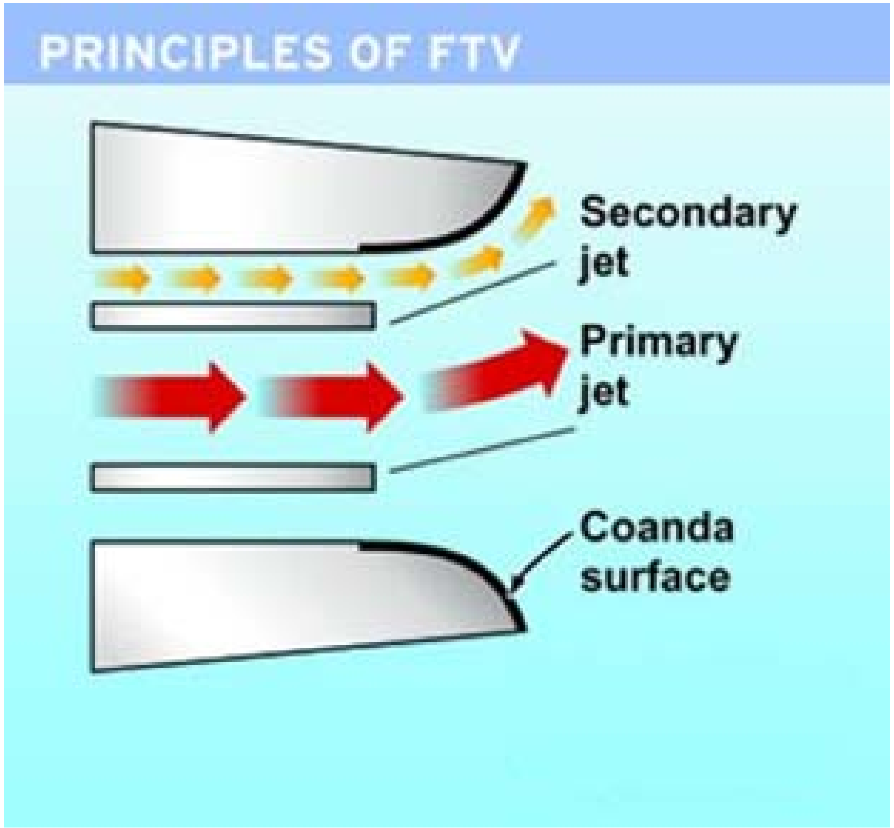
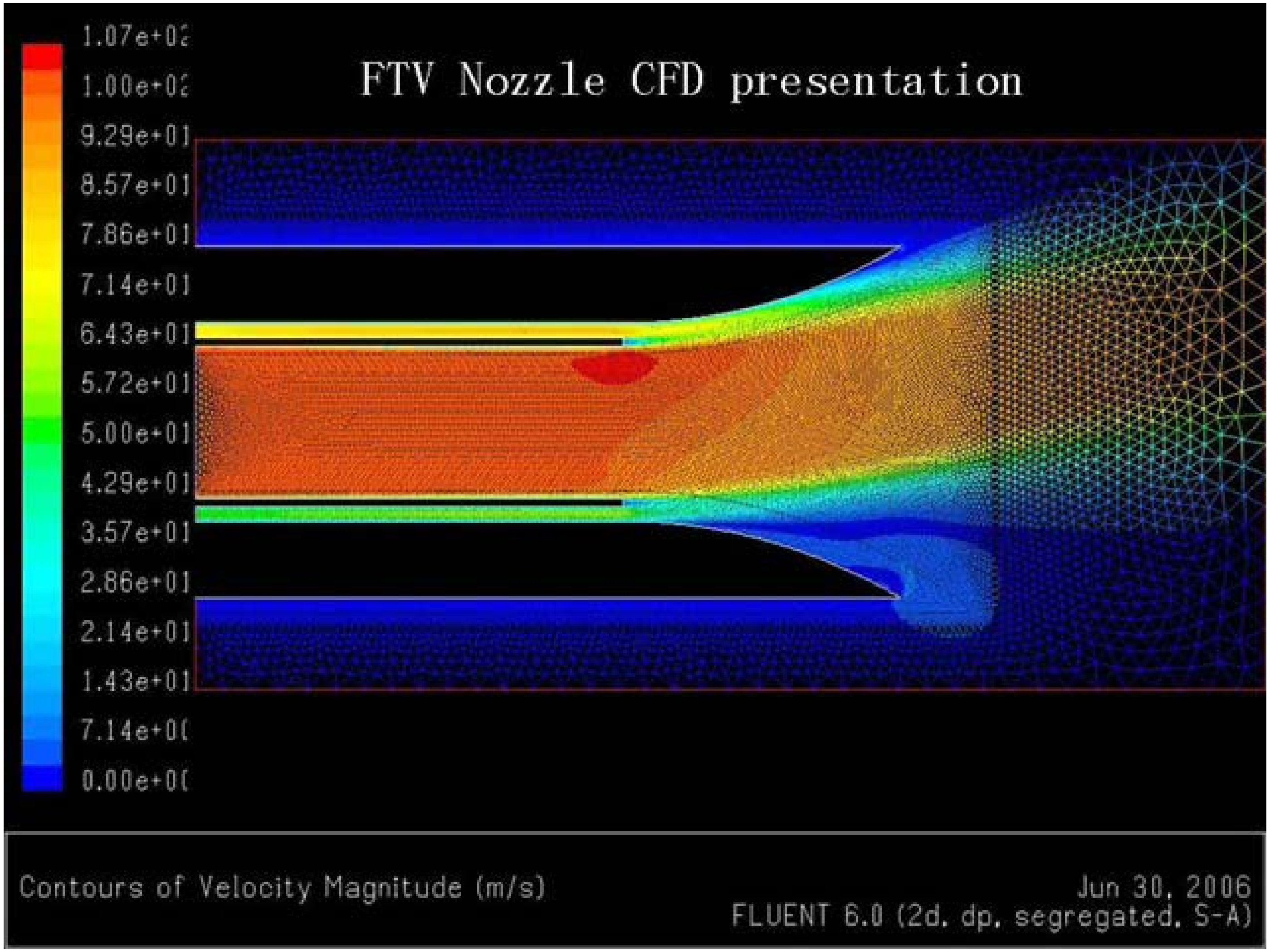
Flapless Technology Review - Circulation Control (CC)



Flapless Technology Review - Fluidic Thrust Vectoring (FTV)



Fluidic Thrust Vectoring CFD simulation



'Seed Corn' Demonstrator Aircraft

'Tutor 40' Dedicated Circulation Control Demonstrator

'Vector II' Dedicated Fluidic Thrust Vectoring Demonstrator

'Santos' Circulation Control and Fluidic Thrust Vectoring (Integrated) Demonstrator

‘Seed Corn’ Demonstrator Aircraft

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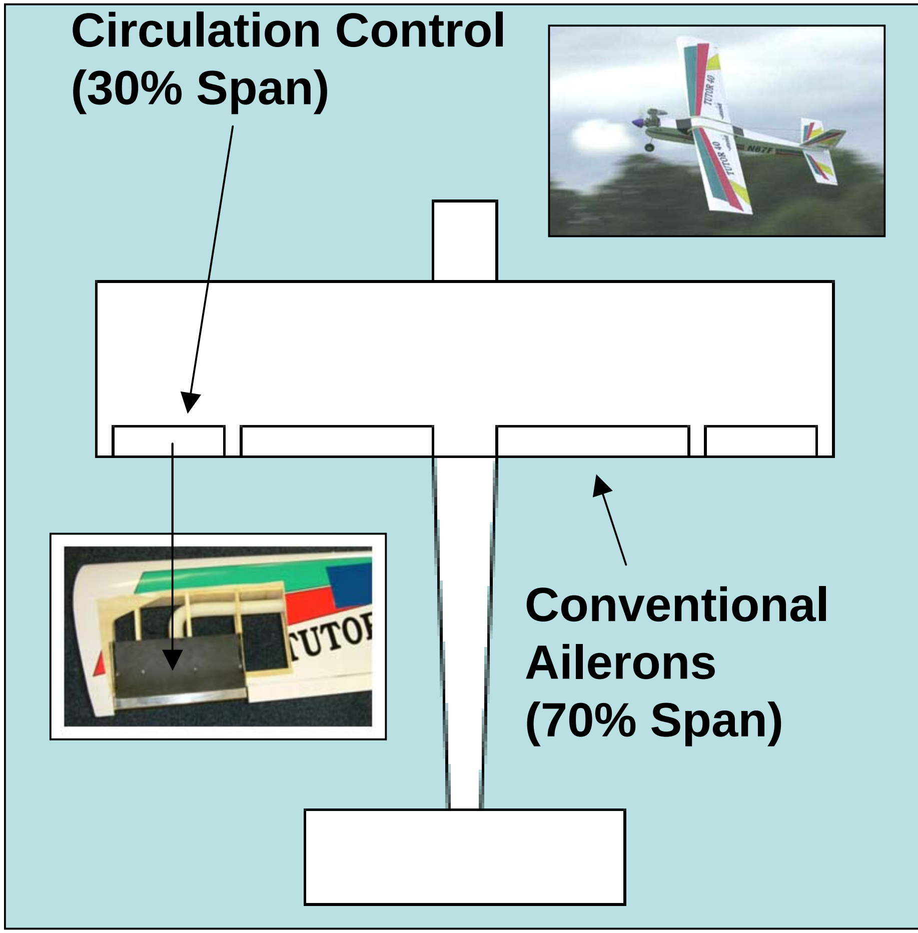
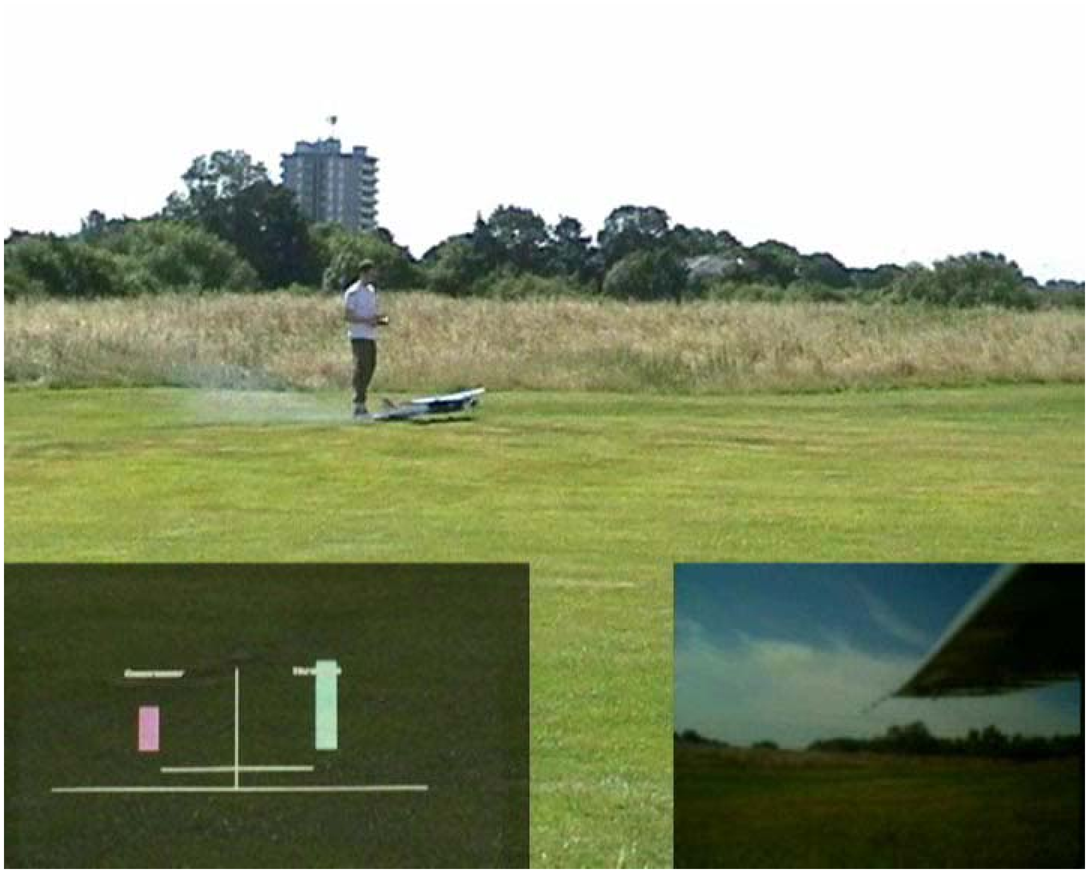
Circulation Control Demonstrator

- Based on an off-the-shelf radio control trainer aircraft known as the Tutor 40
- All up weight 3kg
- Cruise speed 25m/s
- Circulation control implemented along outer 30% of the trailing edge on each wing
- Control air supplied via an electric turbo charger
- Typical CC Jet velocity =75m/s
- Slot height = 0.2mm



Tutor 40 Circulation Control Demonstrator flight – lateral control via CC only (June 2005)



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Circulation Control lessons learnt

Key Technical Development

Flexible slots on the CC plenums provide a simple and reliable method of achieving required tolerances.

CC Demonstrator Experience

The early success of the CC demonstrator was critical in providing confidence for the follow-on demonstrators.

Conclusion

Circulation control was successfully demonstrated through the flight of a model scale demonstrator with circulation control as only means of lateral control.

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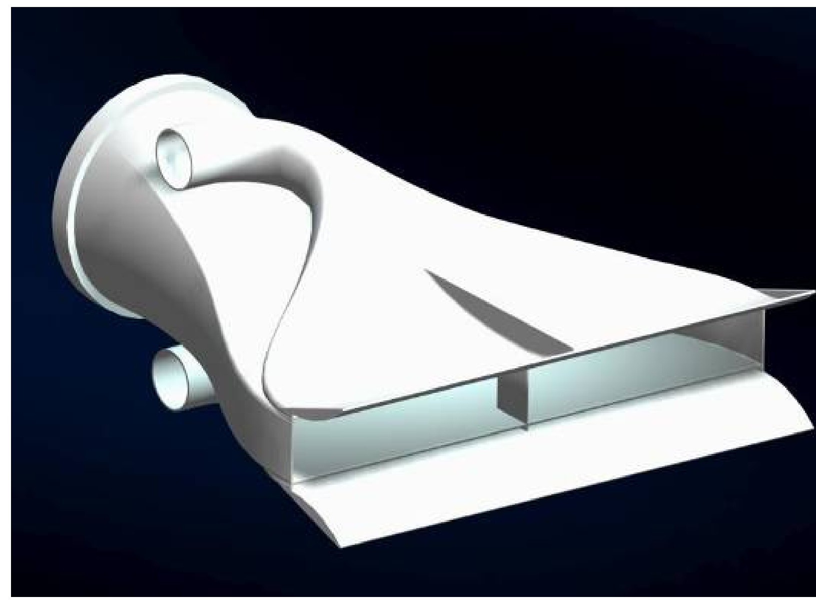
‘Vector II’ Fluidic Thrust Vectoring Demonstrator

- Based on the ‘Vector II’ model aircraft
- Electric ducted fan propulsion
- All up weight 2.25kg
- Cruise speed 30m/s
- FTV nozzle made from ABS plastic using rapid prototyping
- Control air supplied via a dedicated electric ducted fan in fuselage
- Thrust jet velocity 70m/s
- Control jet velocity 140m/s



'Vector II' Dedicated FTV Demonstrator flight -
Pitch control using FTV only during latter part of flight (October 2005)

‘Vector II’ FTV Demonstrator Conclusions

Key Technical Development

Simultaneous blowing was shown to prevent control reversal.

FTV Demonstrator Experience

The project was ended on resolution of most of the integration issues applicable to the full scale demonstrator, however the aircraft was difficult to fly because it was very under powered.

Conclusion

Fluidic thrust vectoring was successfully converted from bench top technology to flight hardware and demonstrated at model scale.

'Seed Corn' Demonstrator Aircraft

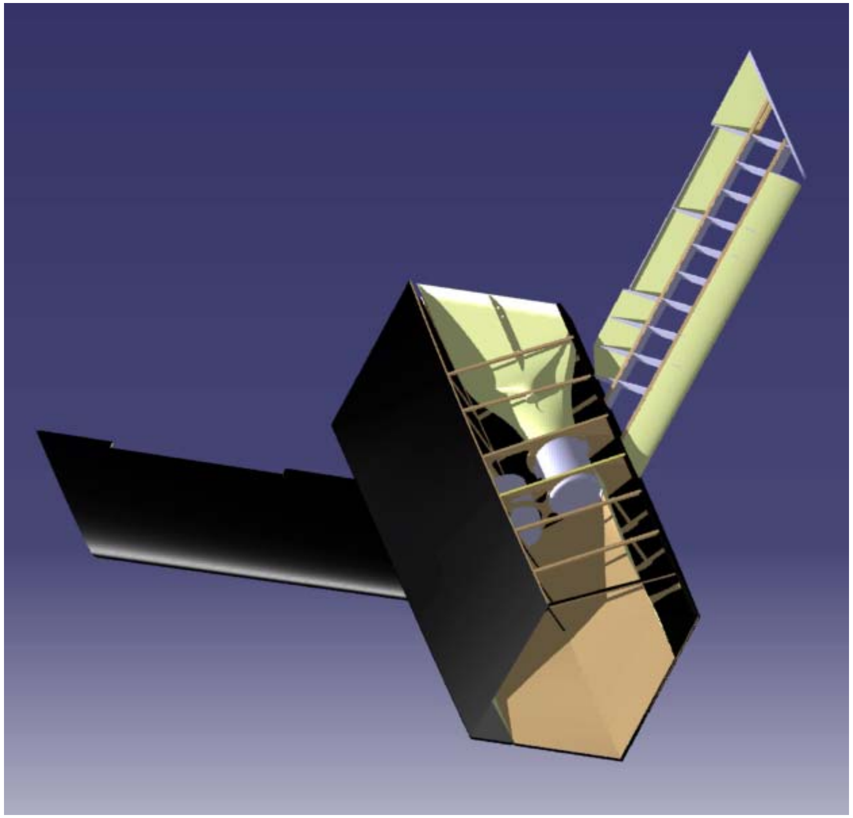
'Tutor 40' Dedicated Circulation Control Demonstrator

'Vector II' Dedicated Fluidic Thrust Vectoring Demonstrator

'Santos' Circulation Control and Fluidic Thrust Vectoring (Integrated) Demonstrator

‘Santos’ Integrated CC +FTV Flight Demonstrator

- Planform based on a Boeing X45 UCAV
- All up weight 6kg
- Cruise speed 30m/s
- Dual electric ducted fans propulsion
- CC + FTV flapless controls + detachable elevons
- ABS plastic FTV nozzles with swept trailing edges
- Control air supplied by electric turbocharger
- R/C control with option for Micropilot FCS
- Traditional wood construction

‘Santos’ Integrated Fluidic Controls – Wind tunnel demonstration

Wind Tunnel Test Results

Circulation Control

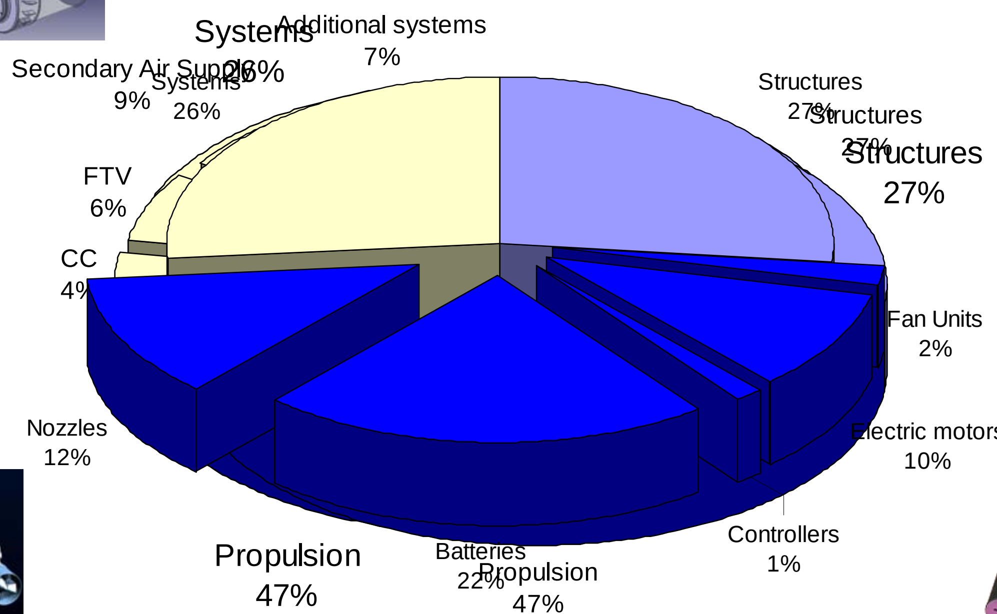
- The CC System was able to generate rolling moments equivalent to 10º of aileron deflection.
- The Santos is capable of a 60º/sec roll rate.

Fluidic Thrust Vectoring

- The FTV generated pitching moments equivalent to 10º of elevon deflection.
- The Santos is capable of performing a 2g manoeuvre.

‘Santos’ first test flight - conventional controls only (March 2006)

‘Santos’ weight breakdown

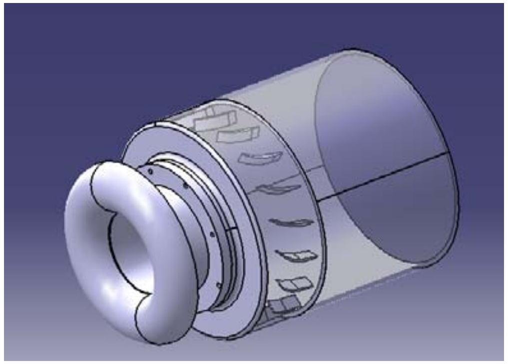


Total weight = 6kg , Flight Time = 4 mins

Flapless Demonstrator Lessons and Developments

Key Development

- The demonstrator proved a useful tool in the evaluation of suitable secondary air supplies for the future Java and Demon demonstrators.



Conclusion

- A flapless aircraft devoid of external moving surfaces has been developed which utilises a FTV and CC system with flow requirements matched to a common secondary air source.

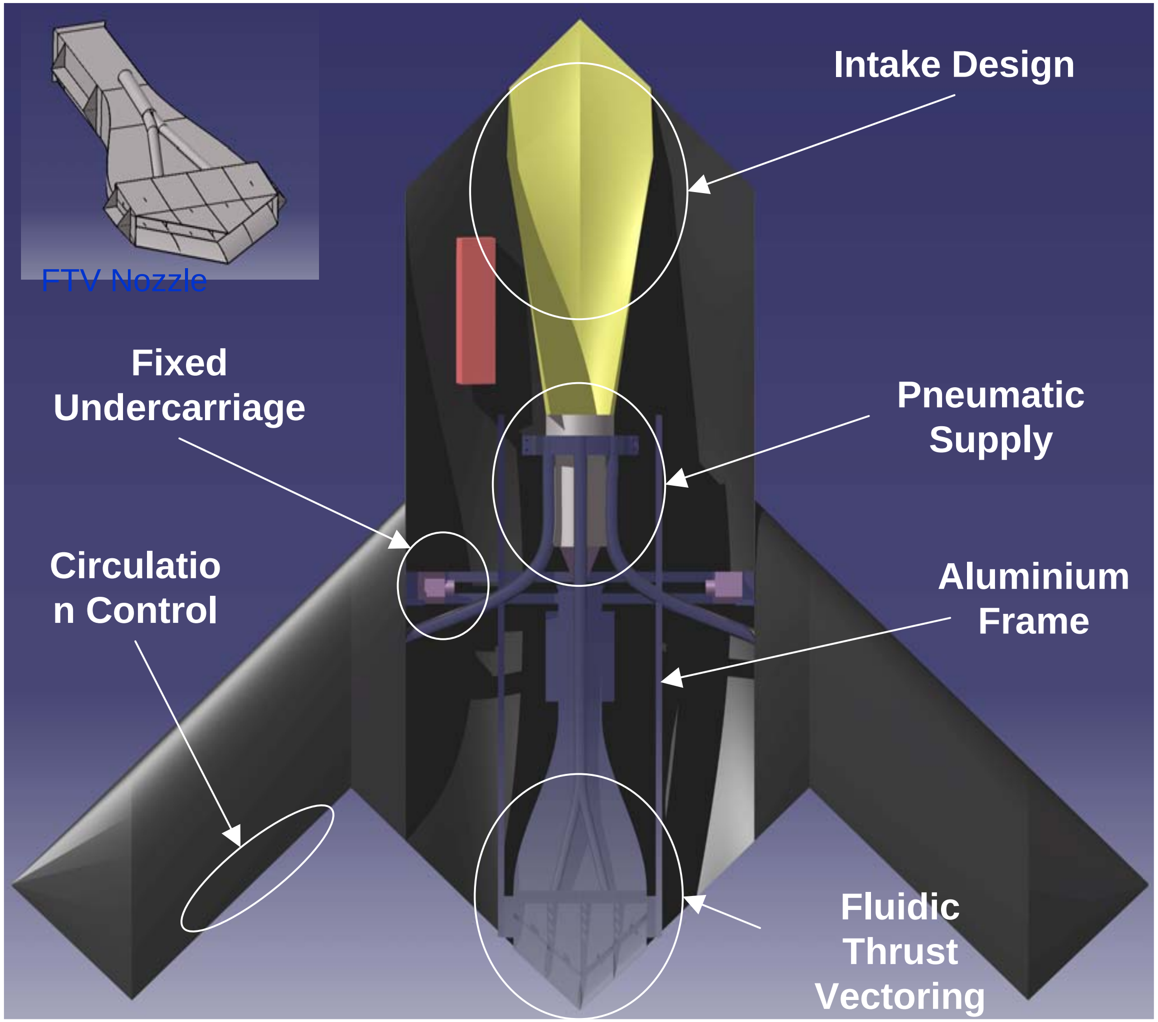
Conclusions from the ‘seed corn’ demonstrator work

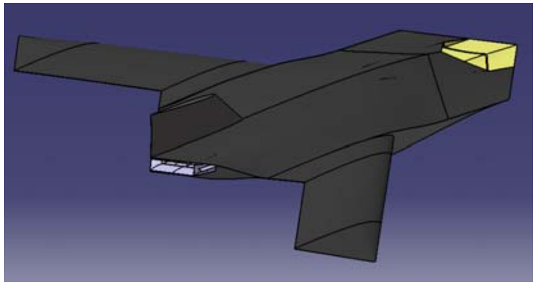
- FTV and CC technologies have been successfully and rapidly transferred from bench top experiments to flight hardware
- Suitable secondary air supplies have been evaluated leading to the choice of an engine bleed solution for future gas turbine powered demonstrators
- Low order design tools have been developed enabling the transfer of the fluidic control technology onto larger class aircraft

Work in progress

- Development of the ‘Java’ mini gas turbine powered flapless demonstrator
- Development of a ‘hot gas’ engine bleed system for mini gas turbines
- Development of a low cost (crashworthy…) flight demonstrator platform for novel flight control system evaluation

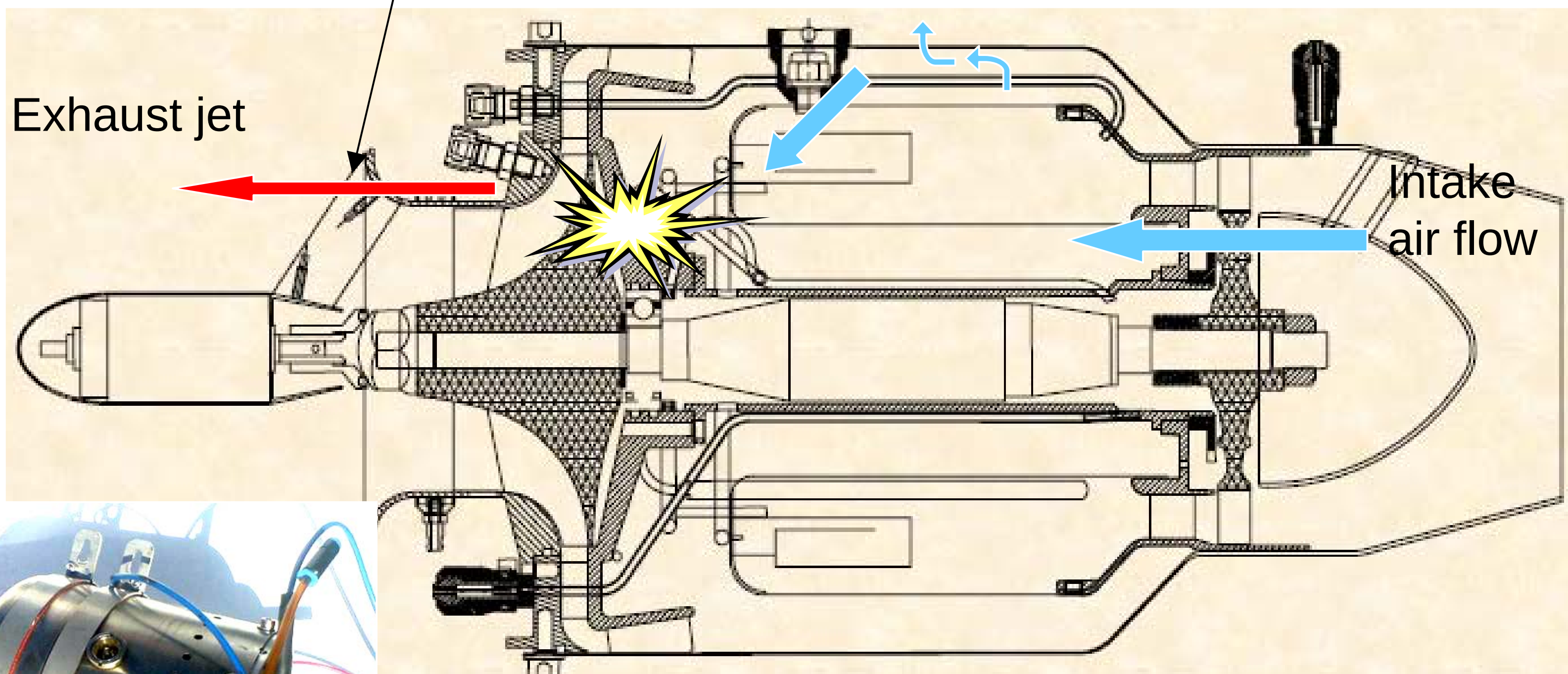
‘Java’ gas turbine powered demonstrator overview

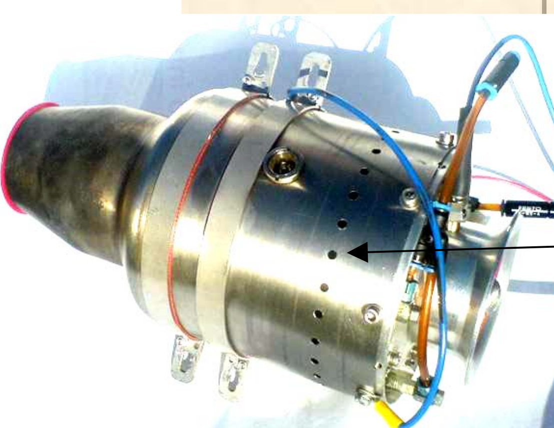




Java Aircraft	
Max Take-Off Weight	15kg
Cruise Speed	40m/s
Wingspan	1.8m
Endurance	12 minutes
Range	25km
Climb Angle	15°
Wing Loading (W/S)	136kg/m^2
Thrust-to-Weight (T/W)	0.44

Engine bleed system for a mini gas turbine





Modified Olympus micro jet engine:

30 x 4mm diameter bleed holes

Conclusions

- Significant progress has been made towards the goal of developing a fully controllable flapless aircraft through flight test of a series of model scale flight demonstrators
- The work has had a significant impact in that it has significantly raised the expectations for the final ‘industrial-scale’ flight demonstrator in the UK-wide FLAVIIR project
- The project has shown that teams of postgraduate students are capable of solving technically challenging problems in very short time scales (by industry standards) given sufficient motivation and resources

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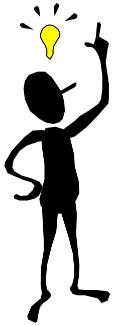
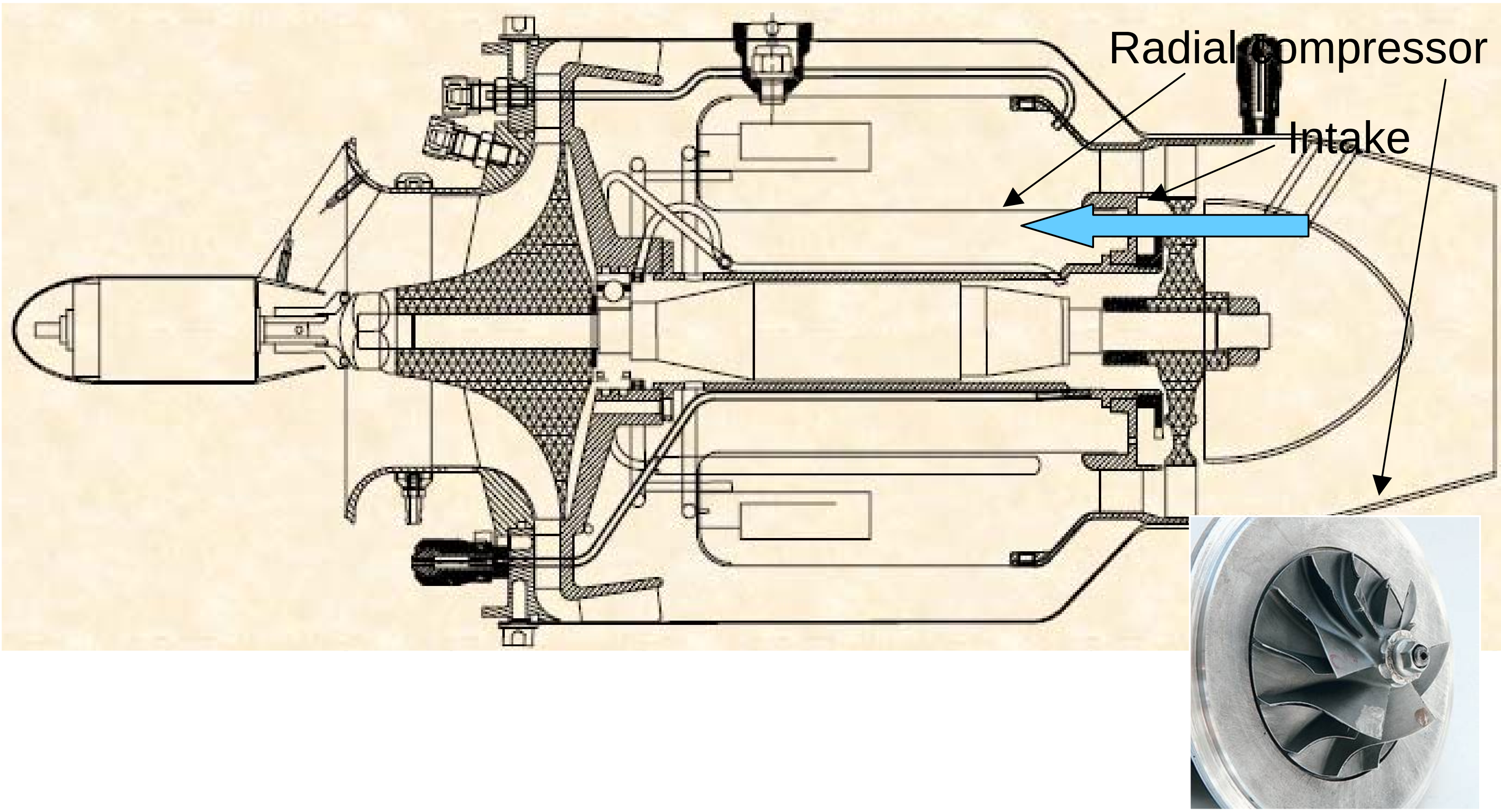
2006 University of Manchester Team Working Award

Demonstrator work – strategies for success?

- The purpose of a demonstrator is to prove a concept or proposition to a group of sceptics
  - It is not always necessary to line up the sceptics in advance – many come forward once you start
- Plan for success, but get used to failure
  - I hate to lose, but I'm not afraid to fail - Thierry Henry
- Demonstrate one thing at a time
  - Early successes boost the confidence of the team and reduce the risk to the overall project
  - Early failures give you the maximum opportunity to learn from your mistakes
- The real research value of demonstrators is in encouraging (forcing) multi-disciplinary teams to work together



Engine bleed system for a mini gas turbine



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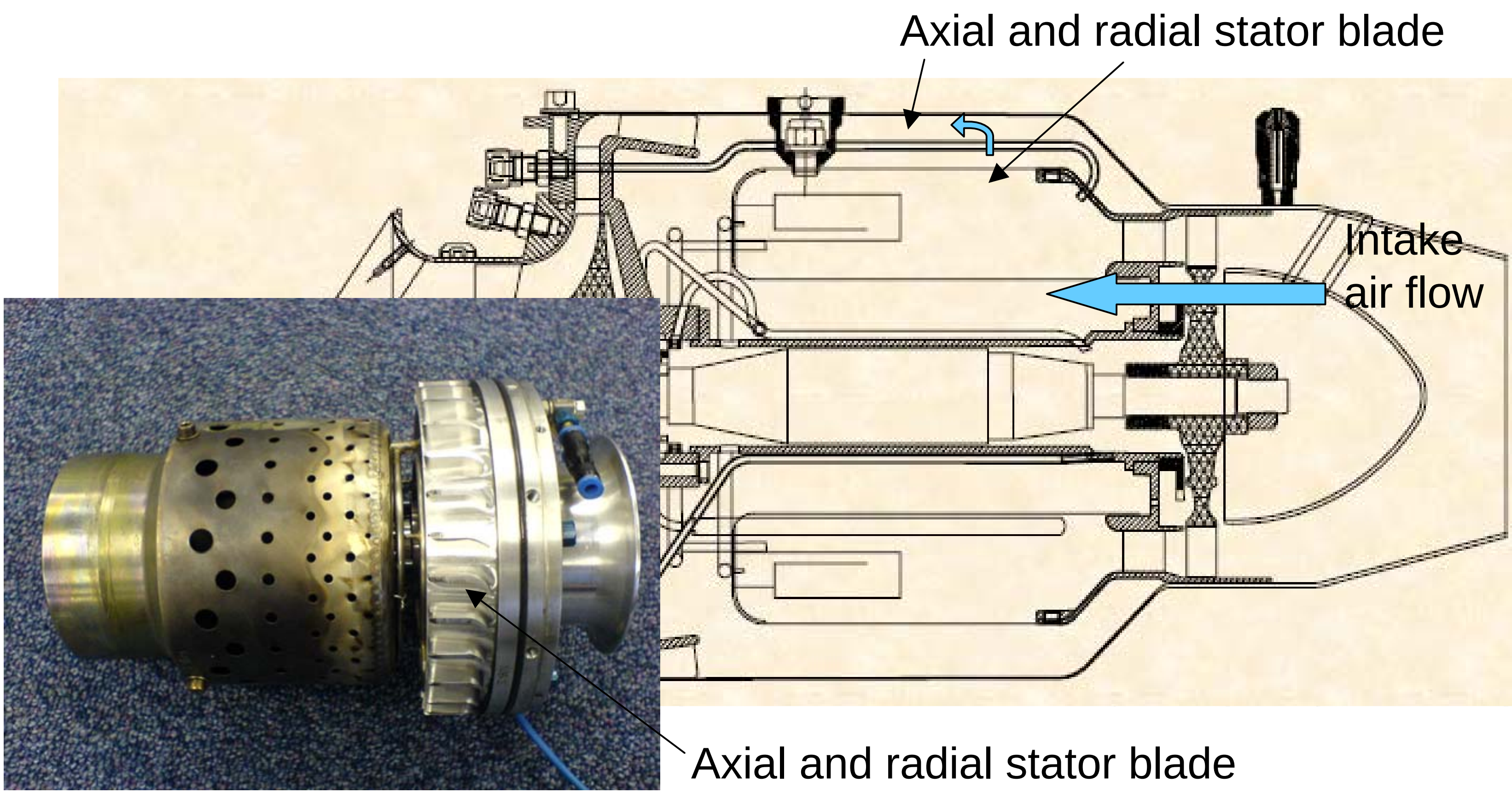
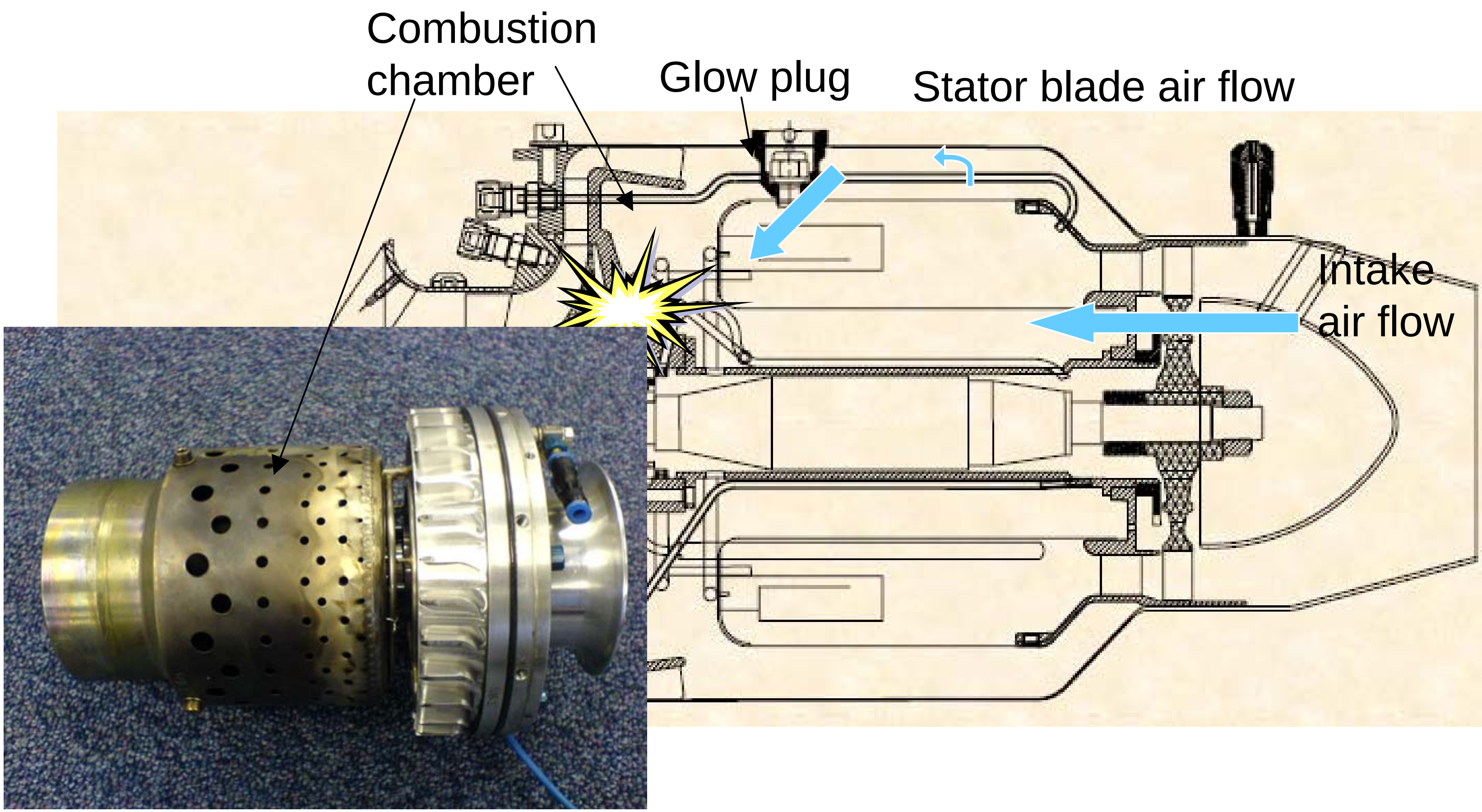


Engine bleed system for a mini gas turbine



Engine bleed system for a mini gas turbine